2012 INTERNATIONAL WORKSHOP ON ENVIRONMENT AND ALTERNATIVE ENERGY

Quantification of Green Roofs' Contributions to Building and Community Performance

Modular system design for vegetated surfaces with alkaline activated materials

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MAIN GOALS

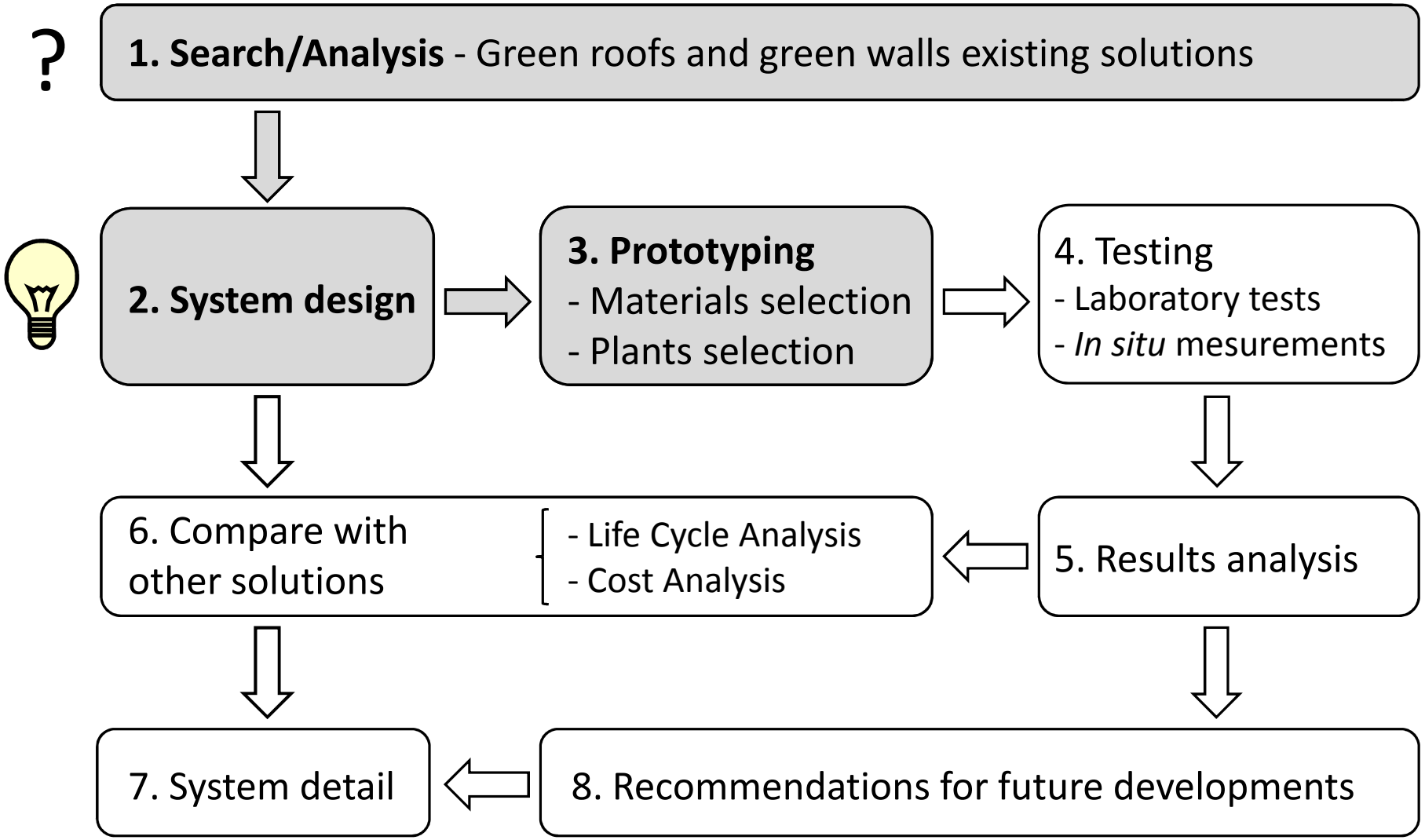
Designing a pre-fabricated modular system with pre-planted vegetation to create vegetated surfaces using alkaline activated materials

- Create a versatile solution for green roofs and green walls
- Simplify the construction process and maintenance
- Integrate sustainability concerns
- Integrate industrial waste materials
- Minimize the system environmental impact
- Improve buildings energy performance
- Use autochthonous/endemic plant species
- Minimize plant irrigation

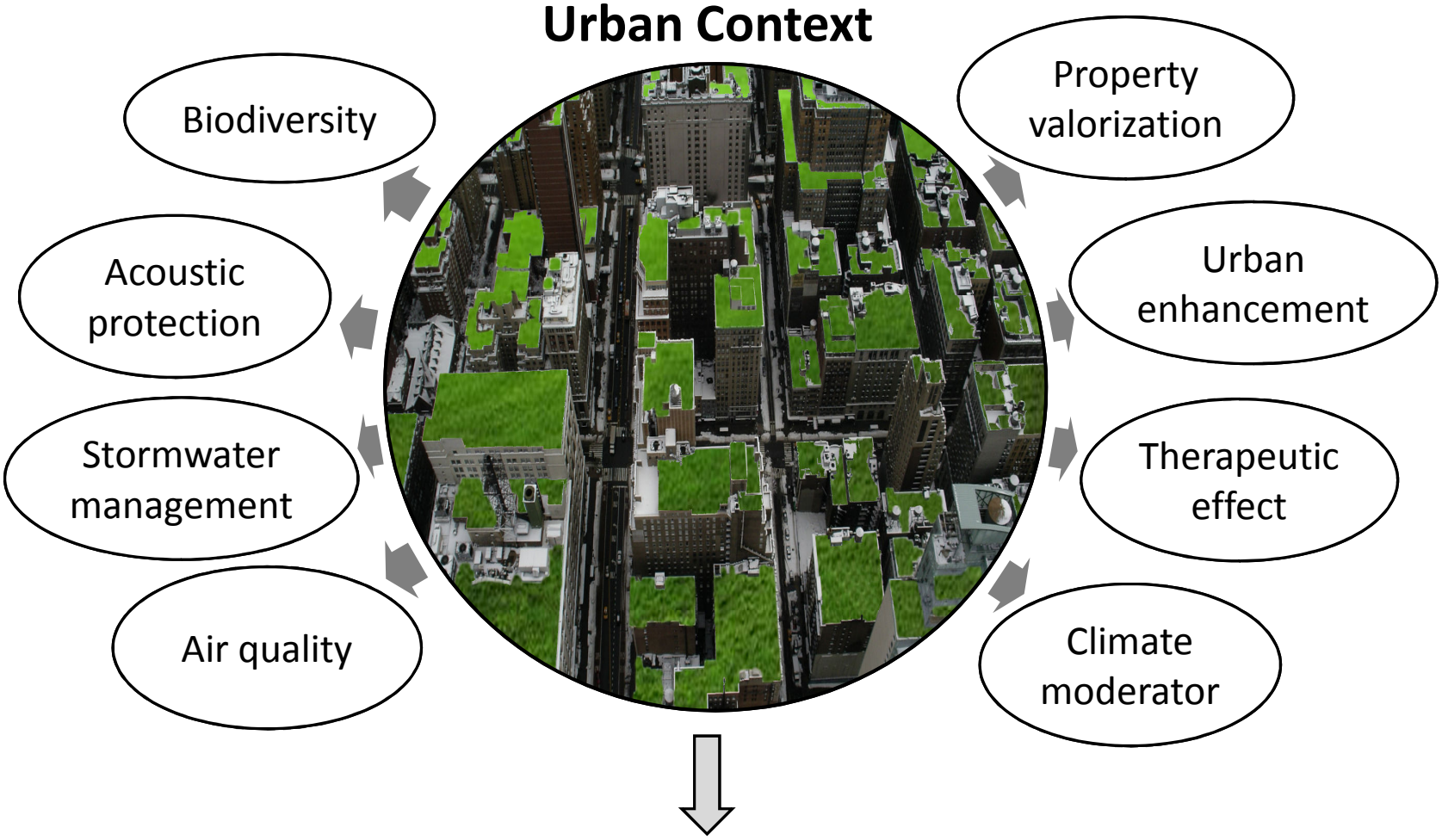
On-going research project

Waste geopolymeric binder-based natural vegetated panels for energy-efficient building green roofs and facades
(Financed by FCT - Foundation for Science and Technology)

METHODOLOGY



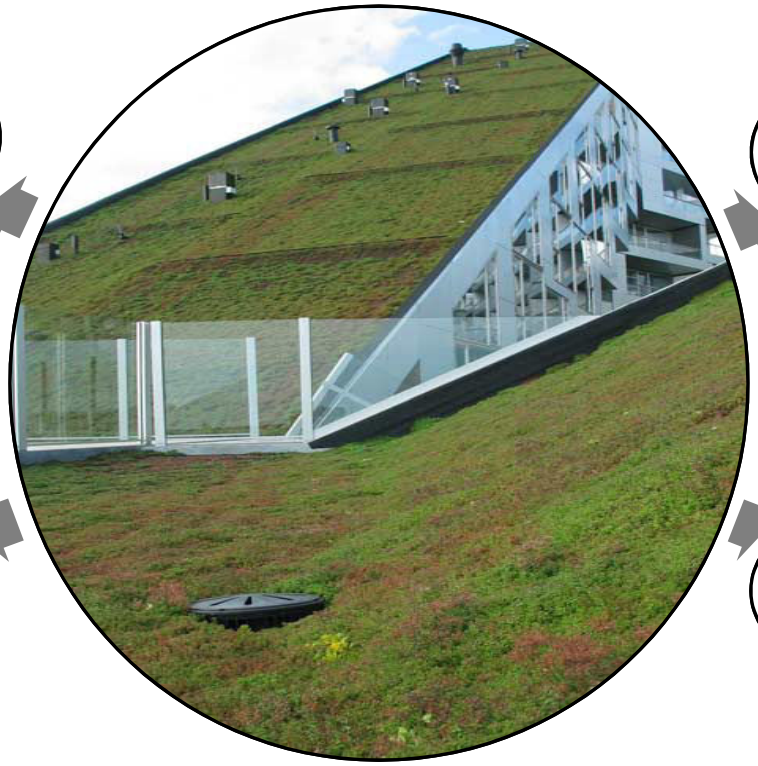
1. SEARCH/ANALYSIS – Benefits



Insertion of vegetation in dense cities without soil occupation

1. SEARCH/ANALYSIS – Benefits

Buildings Performance



Roof longevity

Shadowing

Air quality

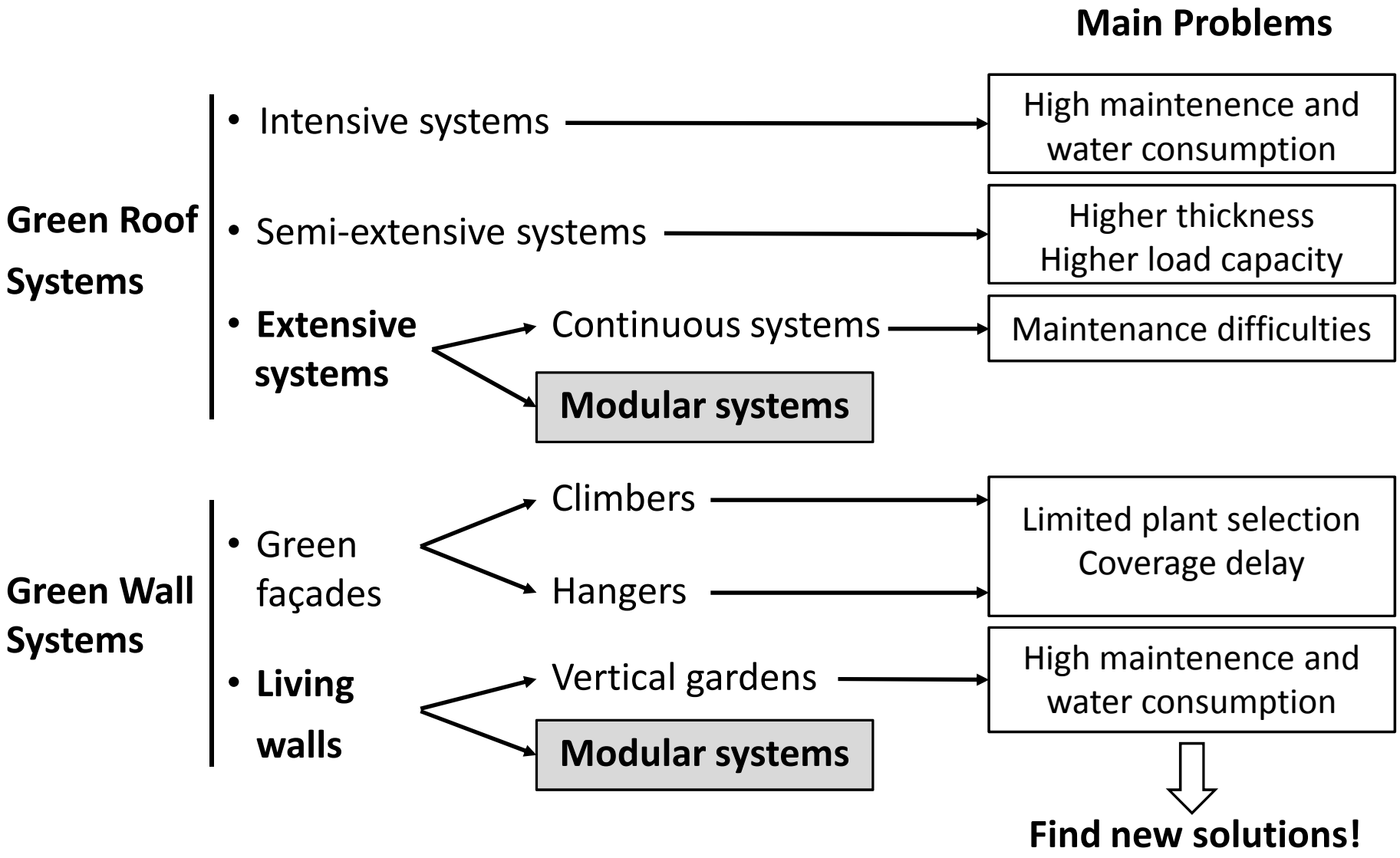
Thermal Protection

Energy consumption reduction

Acoustic protection

Increased confort and costs reduction

1. SEARCH/ANALYSIS - Systems



1. SEARCH/ANALYSIS - Systems

Analysis of green roof and green wall systems – on market or patented

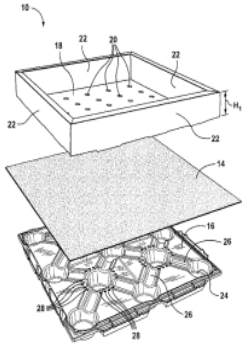
Constructive features/Composition (support, drainage, substrate, vegetation, irrigation)

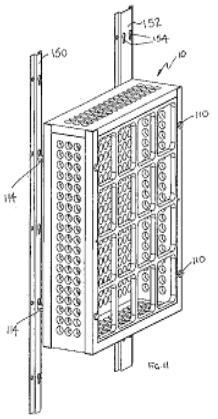
28 Green roof solutions
- 23 Modular systems
- 5 Continuous systems

18 Green wall solutions
- 13 Modular systems
- 5 Continuous systems

Modular systems - Main characteristics

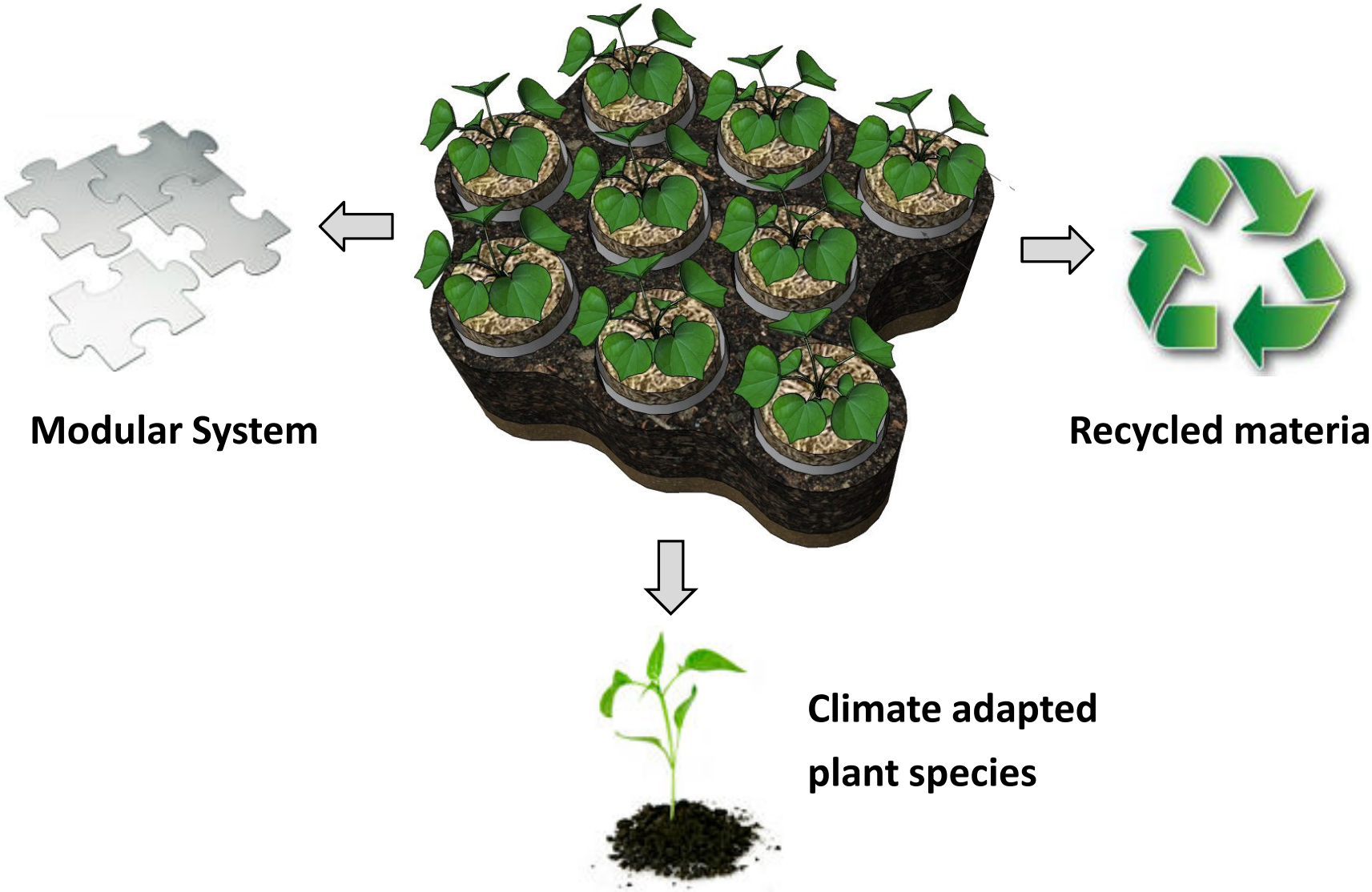
- Containers filled with growing medium
- Light molded reinforced materials (plastic or steel)
- One piece or assembled elements
- Side grooves
- Low density growing mediums
- Plant root and anchor mats (non-woven materials)
- Promote drainage, minimize irrigation and include rainwater recovery





Search for simpler, lighter and effficient solutions

2. SYSTEM DESIGN



Modular System

Recycled materials

Climate adapted plant species

2. SYSTEM DESIGN – MODULAR SYSTEM

- Adaptable to different surfaces and inclinations
- For new buildings and retroffiting
- Based on prefabricated elements
- Ease of assemble and disassemble
- Self-supporting structure

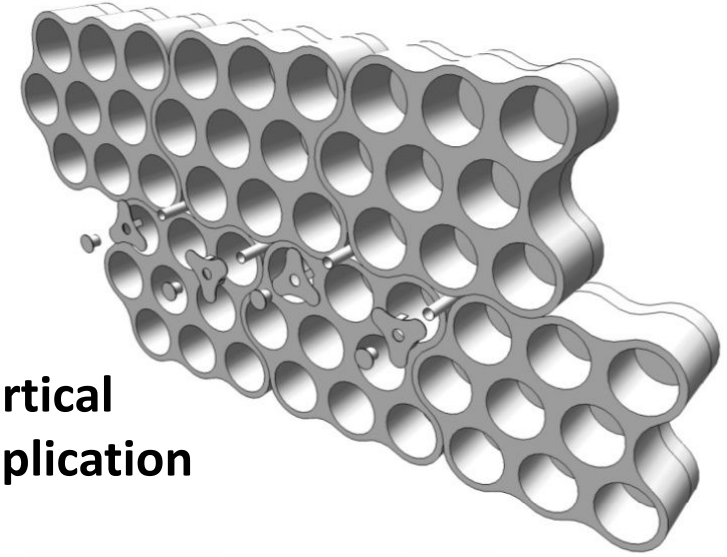
Construction process simplification

Develop a modular system

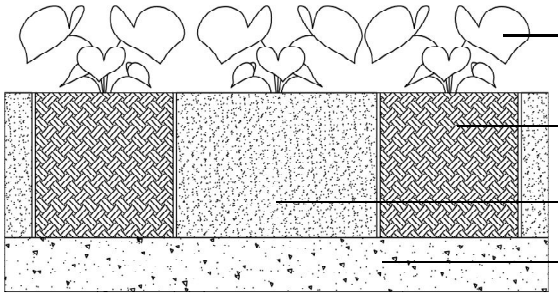
for green roofs and green walls

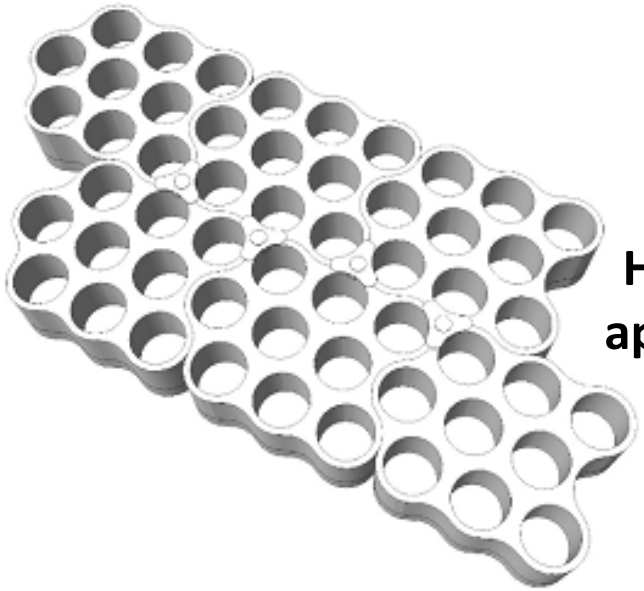
PS1, NY, WORK AC

2. SYSTEM DESIGN – MODULAR SYSTEM



Vertical application





Horizontal application

2. SYSTEM DESIGN – PLANT SPECIES SELECTION

- Herbaceous and shrubby associations
- Adapted to climatic/local conditions and construction restrictions
- Resistant to dry mesomediterranean conditions
  - Dry summers with high temperatures and low humidity
  - Temperate winters with low rainfall index
- Adapted to pH variations, according to the system materials

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- **Minimize adaptation problems**
- **Minimize irrigation requirements**

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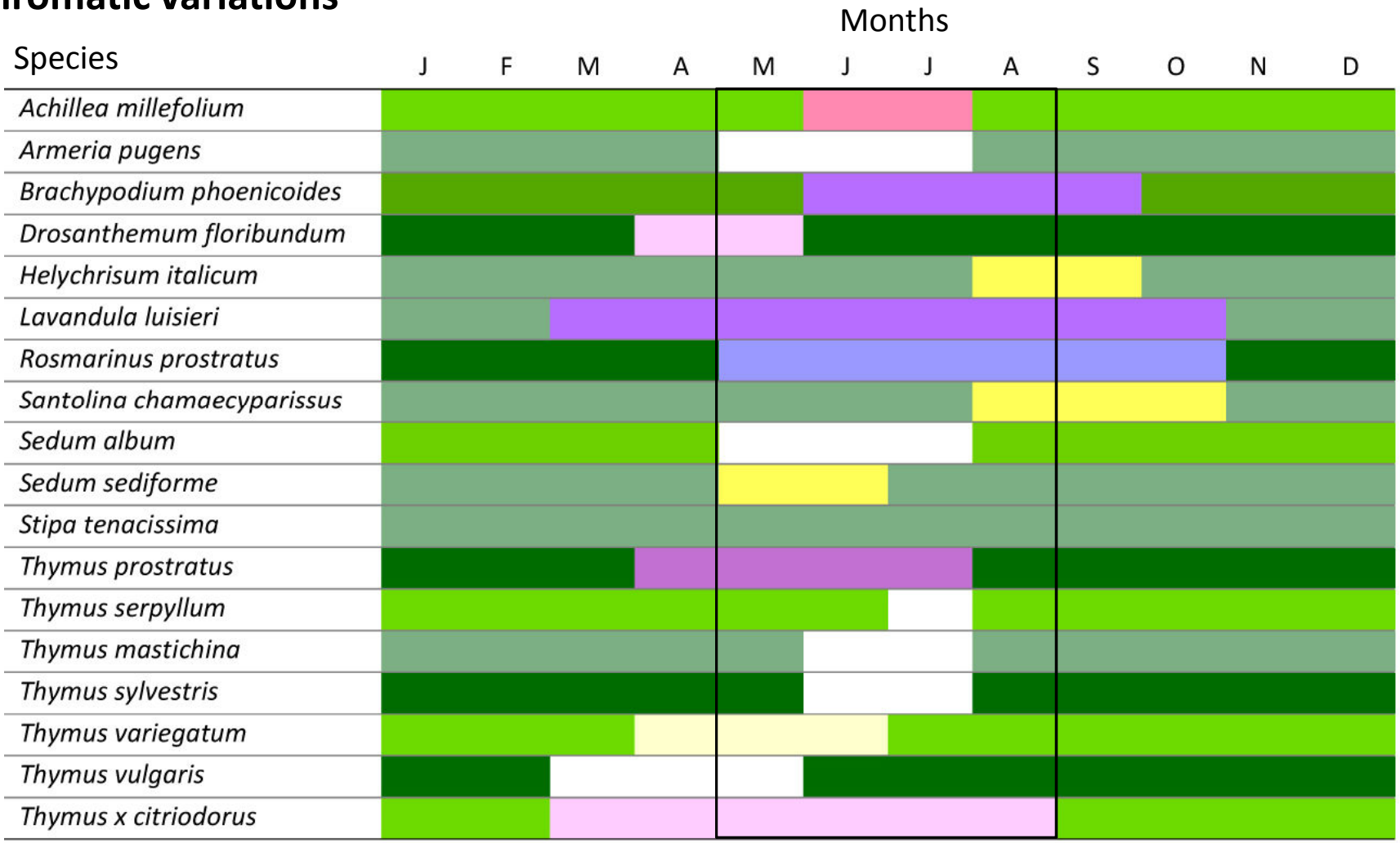
- Testing different irrigation periods
- Testing different substrates

Tests developed in IPCB – ESA

Coordination: Prof. Fernanda Delgado

2. SYSTEM DESIGN – PLANT SPECIES SELECTION

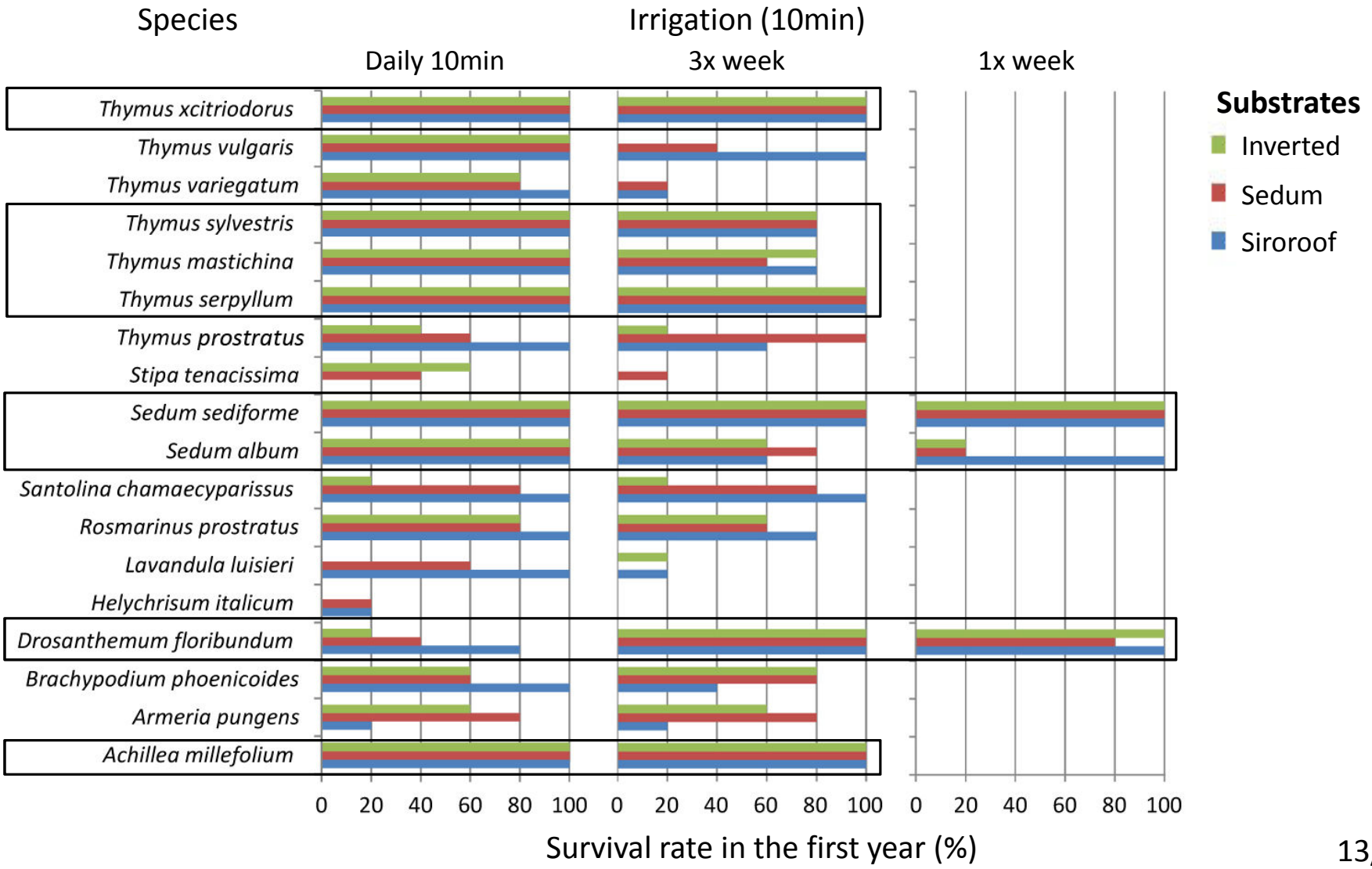
Chromatic variations



Different blooming periods, foliage forms and textures

2. SYSTEM DESIGN – PLANT SPECIES SELECTION

Irrigation tests in different substrates



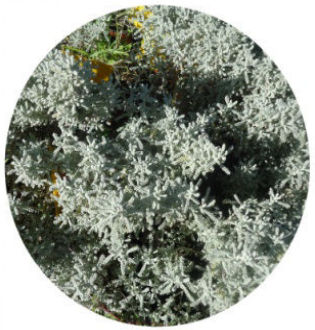
2. SYSTEM DESIGN – PLANT SPECIES SELECTION

- Plants offer an interesting color variation during spring and summer
- Minimum irrigation is required for most plants survival during the first year
- High disintegration of Inverted sedum and Sedum substrates

Achillea millefolium

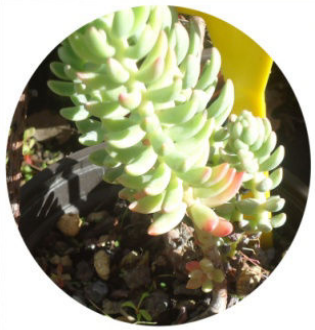
Rosmarinus prostratus

Santolina chamaecyparissus



Sedum album

Sedum sediforme



Thymus prostratus

Thymus serpyllum

Thymus mastichina

Thymus variegatum

Thymus vulgaris

2. SYSTEM DESIGN - MATERIALS SELECTION

Use of industrial waste materials

- **Potentials of alkaline activated materials**
  Knowledge and experience of C-MADE
  in the development of geopolymers
- **Application of expanded cork**
  Experience of production in Portugal
  Low density thermal and acoustic insulator

Geopolymer

Insulation cork board

Sustainability concerns

- Integrate local materials
- Integrate recycled materials
- Minimize the system embodied energy
- Minimize CO_2 emissions

2. SYSTEM DESIGN - MATERIALS SELECTION

55% of industrial waste in Europe is from mines and quarries (Eurostat, 2009)

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Panasqueira tungsten mine in Portugal

Mine waste mud rich in alumino-silicates

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Develop alkaline activated binders or geopolymers

(Solid and stable alumino-silicate material)

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Tested geopolymers characteristics

Density, Porosity, Mechanical strength,

Fire resistance, Durability, Resistance to acid attack,

Environmental performance in leaching tests

Mine waste mud

2. SYSTEM DESIGN - MATERIALS SELECTION

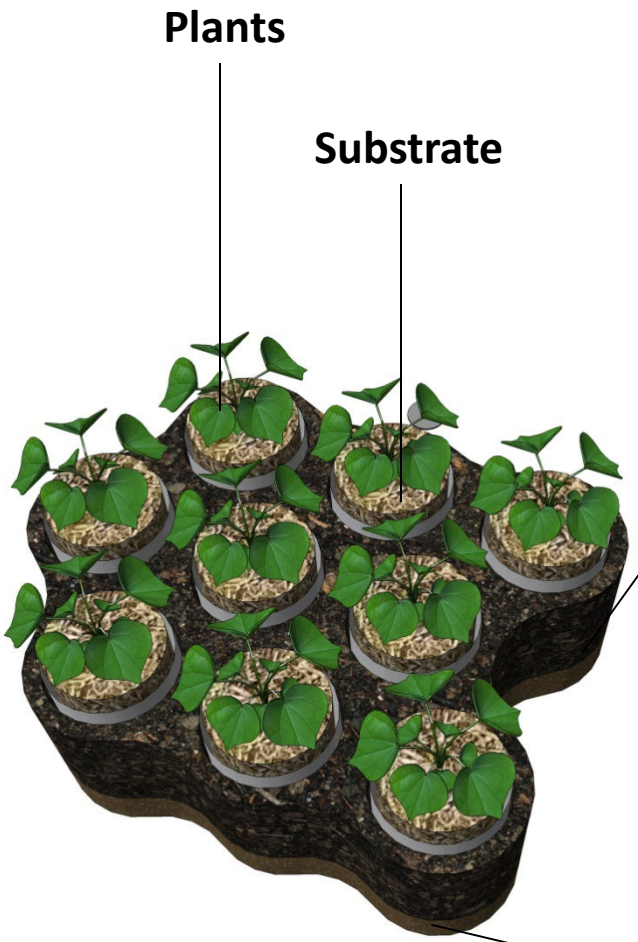
Optimal geopolymeric combination?

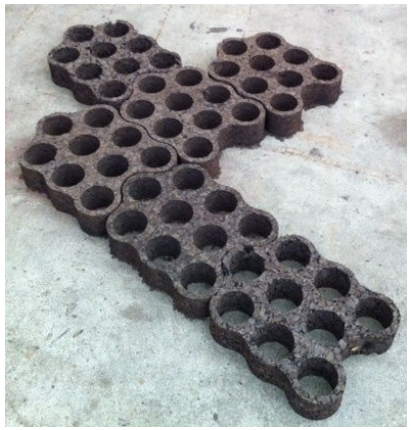
Percursors	Activators	Aggregates
Non-calcinated mine waste mud Other minerals	Sodium silicate Sodium hydroxide	Recycled materials

Testing several geopolymeric mixtures

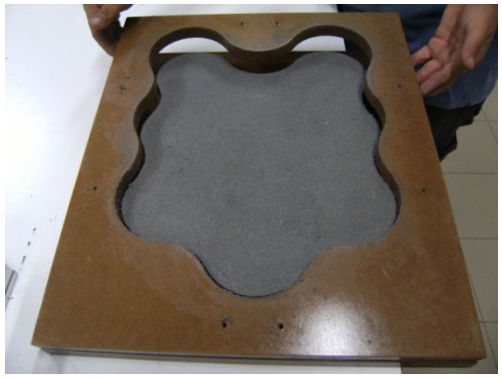
Increased porosity + **Lower density** + **Compression resistance**

3. PROTOTYPING





Superior plate – SOFALCA Insulation cork board (ICB)
Low density natural insulator to handle the substrate

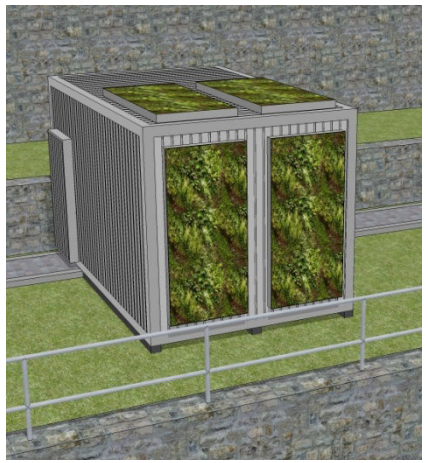


Base plate - Porous geopolymer
Absorbs water and releases it slowly into the substrate

FOLLOWING DEVELOPMENTS

4. Testing - Real climate studies

- Cell test infrastructure (meteorological station, thermal and hygrometric sensors)
- Determine the energy efficiency of different solutions
- Evaluate the modular system potential as passive cooling system



PRELIMINARY CONCLUSIONS

- Modular system must be detailed and tested (structure, irrigation and drainage)
- Select the plant species with more resistance to less irrigation and climate conditions
- Identify the geopolymer mixture with best combination of porosity, density and strength

Thank you for your attention

Obrigada!

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